Session 3

White-Box Testing

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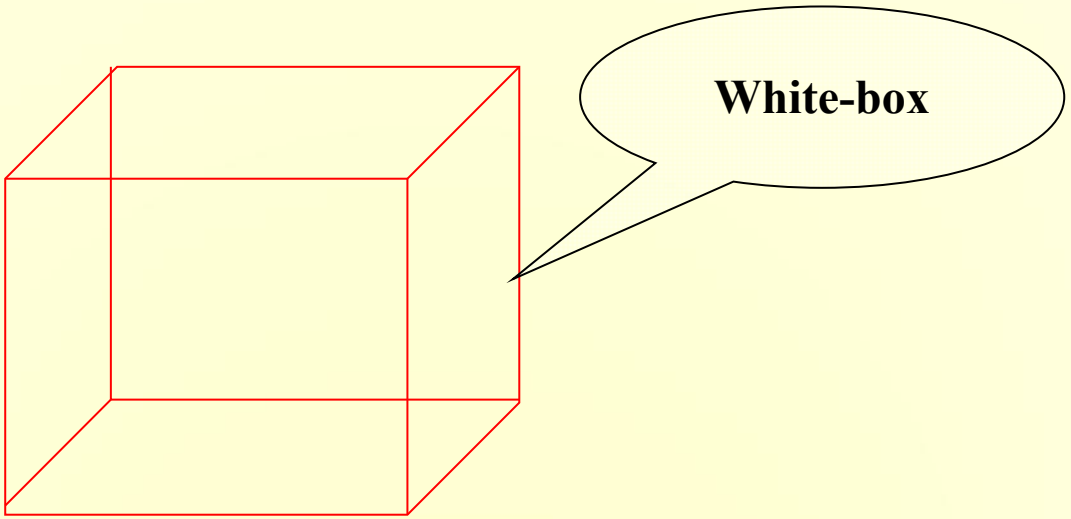
Objectives

- In this session, you will learn
  - **Basic Concepts of White box testing**
  - **Logic Coverage**
  - **Control Flow Graph**
  - **Basis Path Testing**
  - **Loop Testing**
  - **Data Flow Testing**

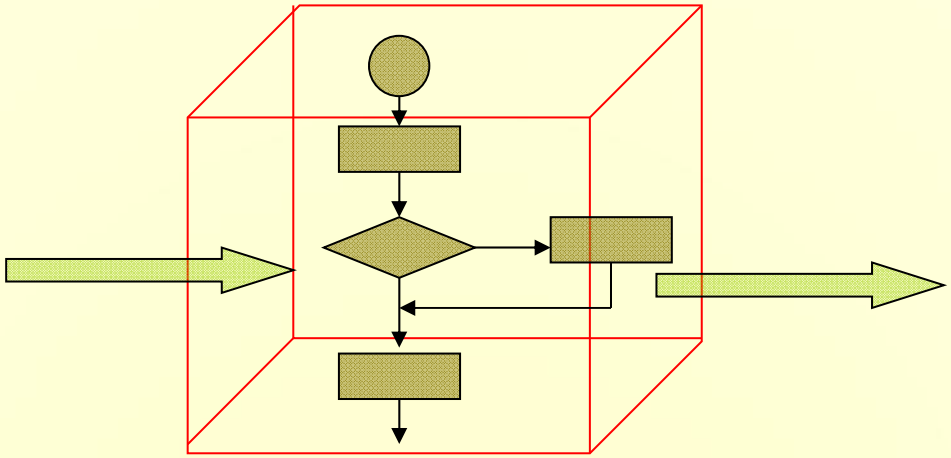
3.1 Basic Concepts

- White-box testing
  - It is a validation technique software engineers can use to examine if their code works as expected.
  - It is also known as structural testing, clear box testing, and glass box testing.



3.1 Basic Concepts

* White-box testing
  * It indicates that you have full visibility of the internal workings of the software product, specifically, the logic and the structure of the code.

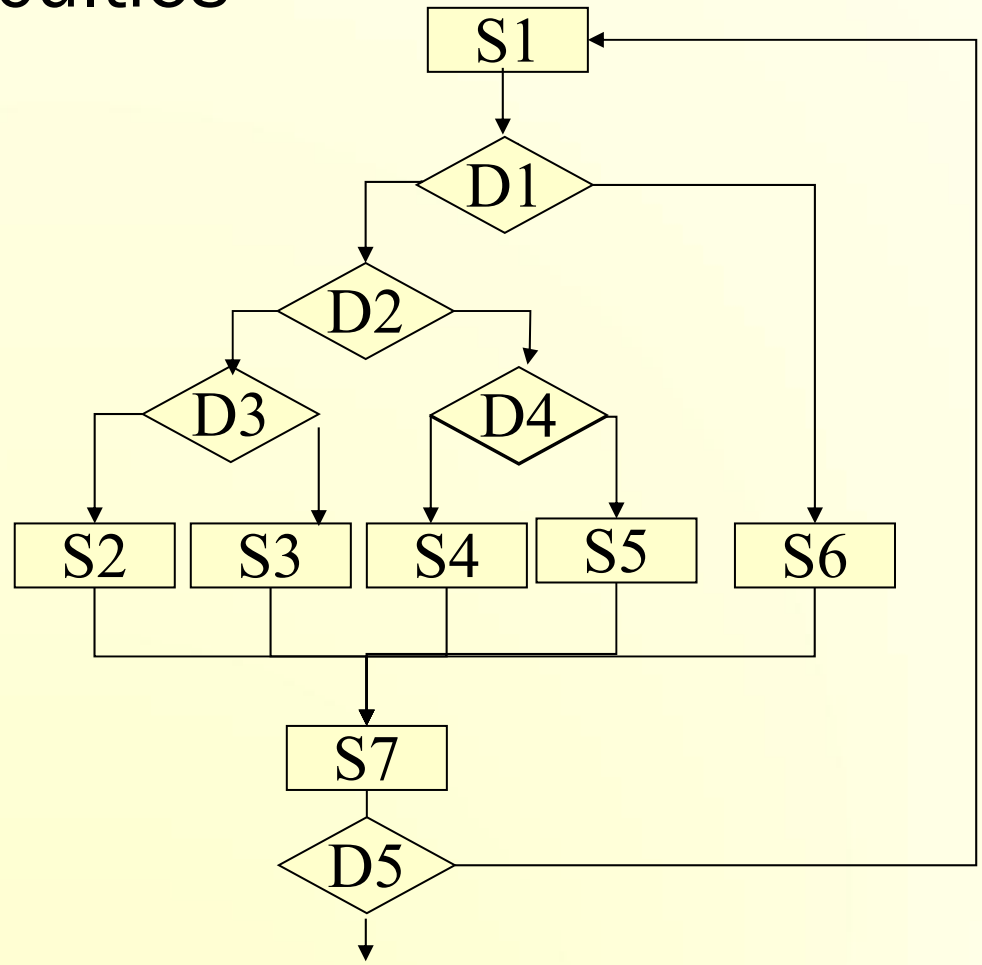


3.1 Basic Concepts

	White-box Testing	Black-box Testing
程序结构	已知程序结构	未知程序结构
规模	小规模测试	大规模测试
依据	详细设计说明、源代码	需求说明、概要设计说明
面向	程序结构	输入输出接口/功能要求
适用	单元测试	集成、系统、验收测试
测试人员	开发人员	专门测试人员/外部人员(用户)
优点	能够对程序内部的特定部位进行覆盖	能站在用户的立场上进行测试
缺点	无法检验程序的外部特性,不能检测对需求的遗漏	不能测试程序内部特定部位,如果规格说明有误，则无法发现

3.1 Basic Concepts

* White-box Testing Difficulties
  - **For multiple choices and nesting cycle of the procedure, the number of different possible paths is astronomical.**
  - **cycle≤20times**
  - **Different paths is 5^{20},if the implementation time of each path is 1 ms , 3170years are needed.**



3.1 Basic Concepts

* Why we can't use exhaustive testing?
  * Time consuming is expensive.
  * Path exhaustive testing can't detect the wrong because of path omission.
  * Path exhaustive testing can not discovery some errors associated with the data.(eg. boundary, specific input)

3.1 Basic Concepts

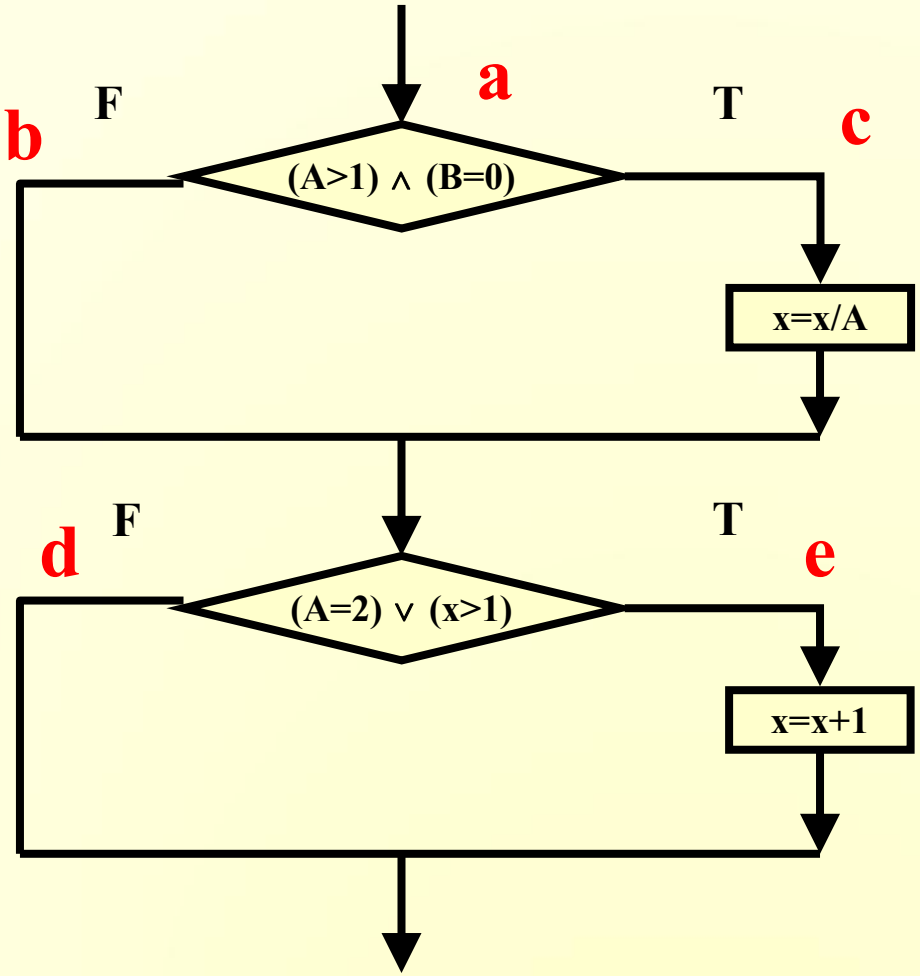
* White-box testing must follow several principles:
  * All *independent* path in a module must be implemented at least once. (Basis path testing)
  * All logic values require two test cases: true and false. (Logic coverage)
  * Inspection procedures of internal data structure, and ensuring the effectiveness of its structure. (Static Testing + Data Flow Testing)
  * Run all cycles within operational range. (Loop testing)

3.2 Logic Coverage

* Logic coverage
  * Statement Coverage
  * Decision Coverage
  * Condition Coverage
  * Condition-Decision Coverage
  * Condition Combination Coverage
  * Path Coverage
  * Complete Coverage
  * Modified Condition/Decision Coverage

3.2 Logic Coverage

* Flow Chart of Sample Code



Path:

L1(a→c →e)

L2(a→b →d)

L3(a→b →e)

L4(a→c →d)

3.2 Logic Coverage—Statement Coverage

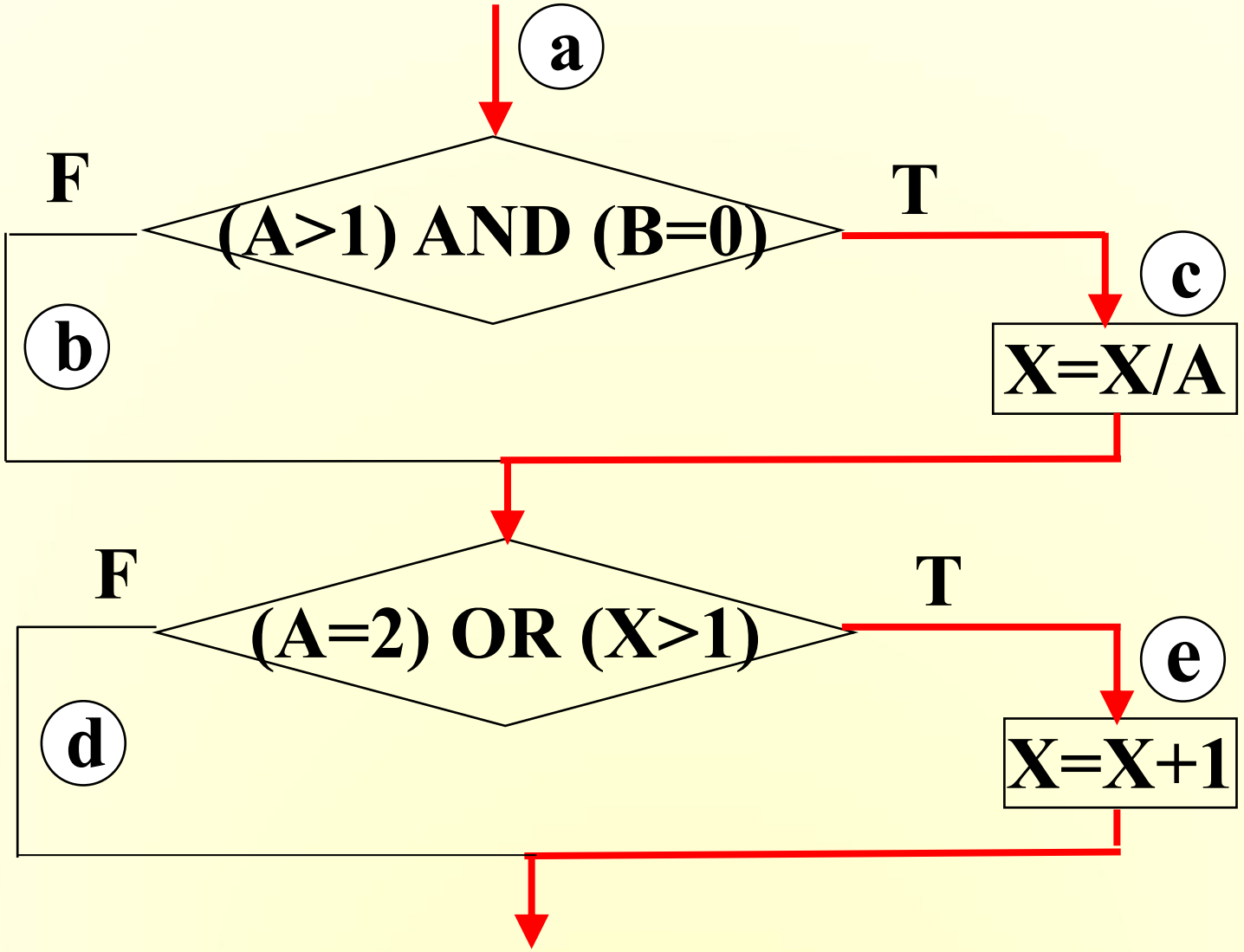
- Statement coverage（*语句覆盖*）
  - Statement coverage is to design a number of test cases, making each executable statement implement at least once.
  - In diagram, all the executable statements are in the path L1, so choose path L1 to design test case

3.2 Logic Coverage—Statement Coverage

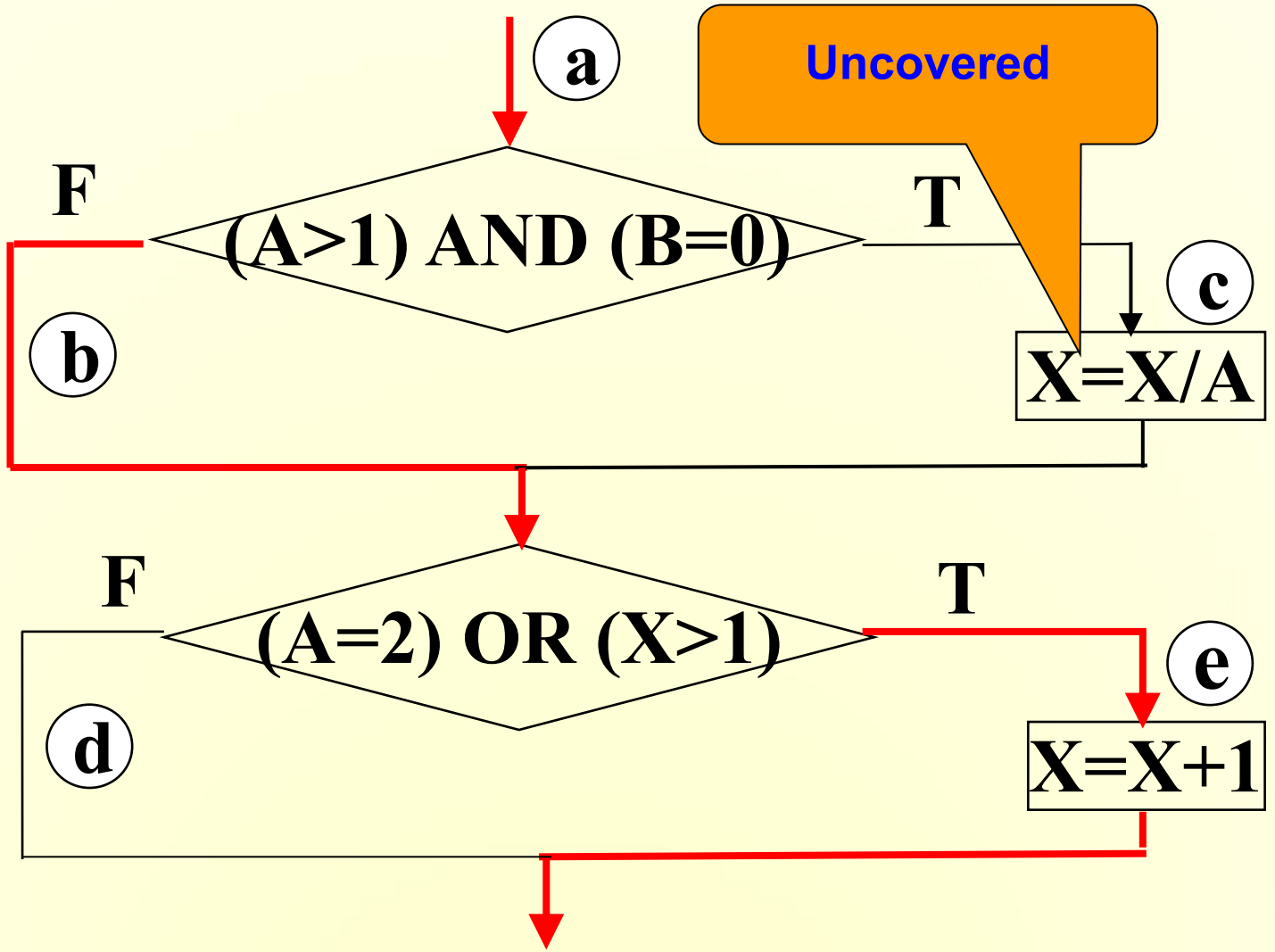
L1:[(A=2) and (B=0)] or [(A>1) and (B=0) and (x/A>1)]

TC	A	B	X	Path
Case1	2	0	3	ace √
Case2	2	1	3	abe ×

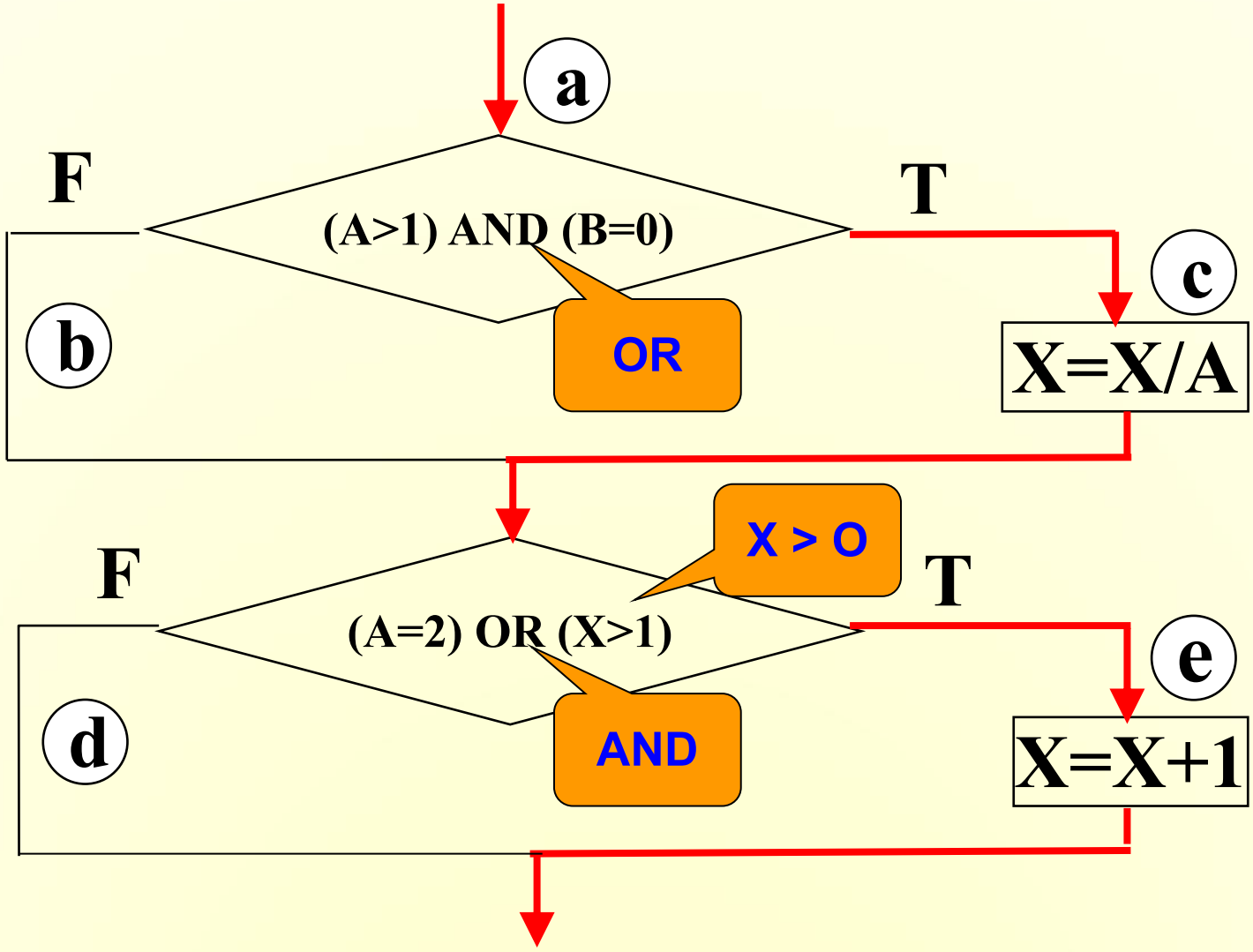
Case1： A=2, B=0, X=3



Case2： A=2, B=1, X=3



Case1： A=2, B=0, X=3



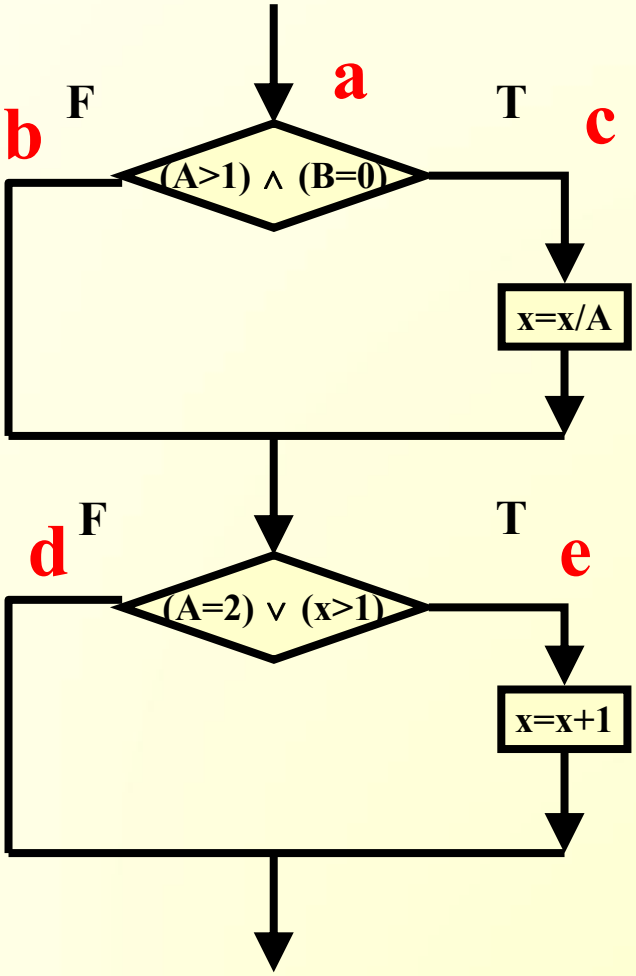
Statement coverage is weakest

3.2 Logic Coverage—Decision coverage

- Decision Coverage（*判定覆盖*） is to design a number of test cases, make the true and false branches of each judgment may go through at least once.

- “Switch--Case” – each braches

3.2 Logic Coverage—Decision coverage



Path:

L1(a→c →e)

L2(a→b →d)

L3(a→b →e)

L4(a→c →d)

(2, 0, 3) covers ace【L1】

(1, 1, 1) covers abd【L2】

or

(2, 1, 1) covers abe【L3】

(3, 0, 3) covers acd【L4】

3.2 Logic Coverage—Decision coverage

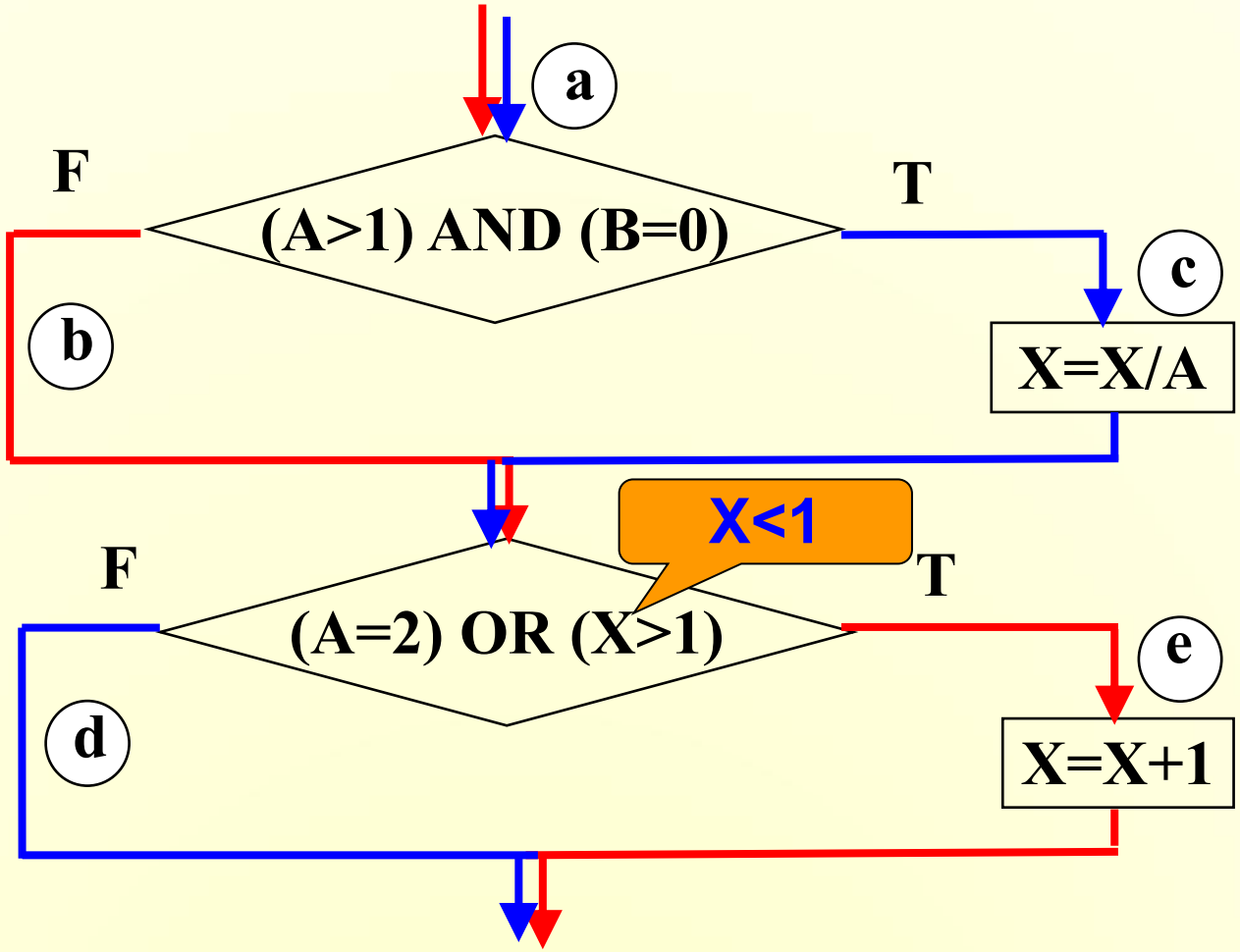
* Please consider that
  * If x>1 is written wrong as x<1
    * t1 (2, 0, 3) t2 (1, 1, 1)
    * t3 (2, 1, 1) t4 (3, 0, 3)

Decision Coverage is not guaranteed they can detect the wrong conditions in judgment

Eg.

Case3： A=2, B=1, X=1

Case4： A=3, B=0, X=3



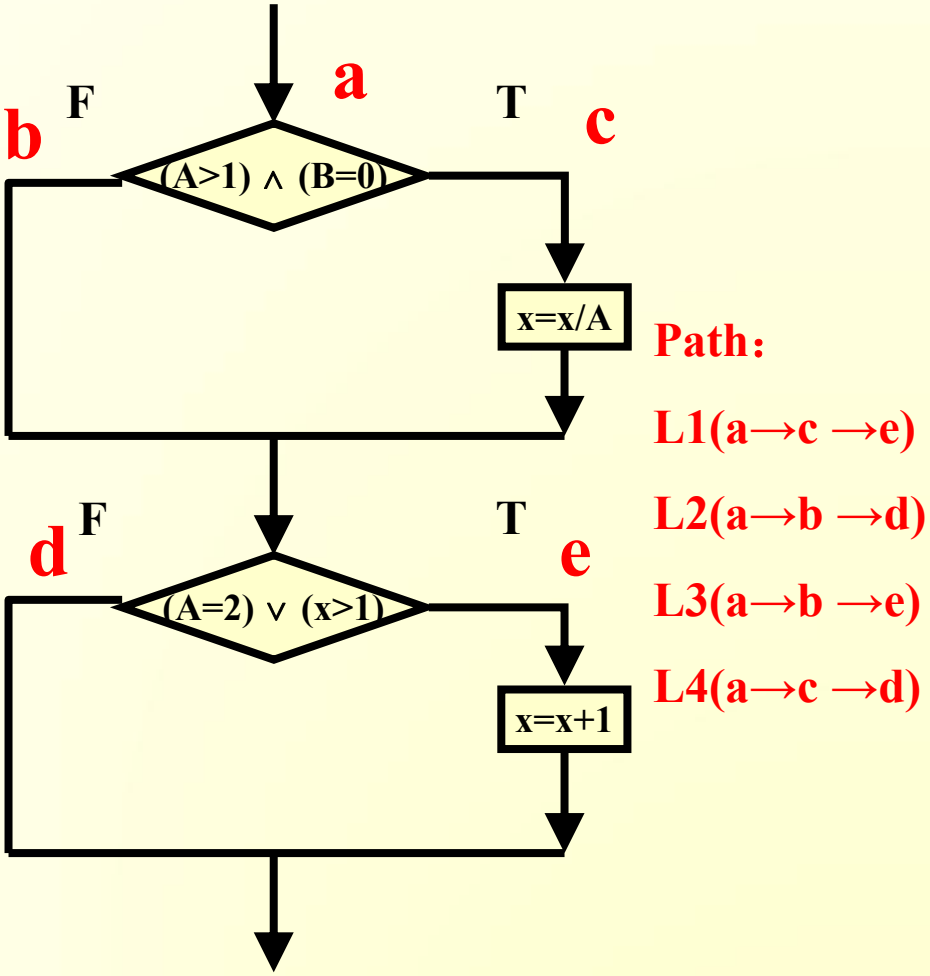
Decision coverage is not strong enough.

3.2 Logic Coverage—Condition coverage

* Conditions coverage（*条件覆盖*） is to design a number of test cases, make possible values of each condition in the procedure may implement at least once.

* Decision vs. condition

3.2 Logic Coverage—Condition coverage



Path:

L1(a→c →e)

L2(a→b →d)

L3(a→b →e)

L4(a→c →d)

For the first judgment

Condition A＞1 true value is T1，false value is !T1

Condition B＝0 true value is T2，false value is !T2

For the second judgment

Condition A＝2 true value is T3，false value is !T3

Condition X＞1 true value is T4，false value is !T4

3.2 Logic Coverage—Condition Coverage

Test case
(2, 0, 4)
(1, 1, 1)

Test case
(1, 0, 3)
(2, 1, 1)

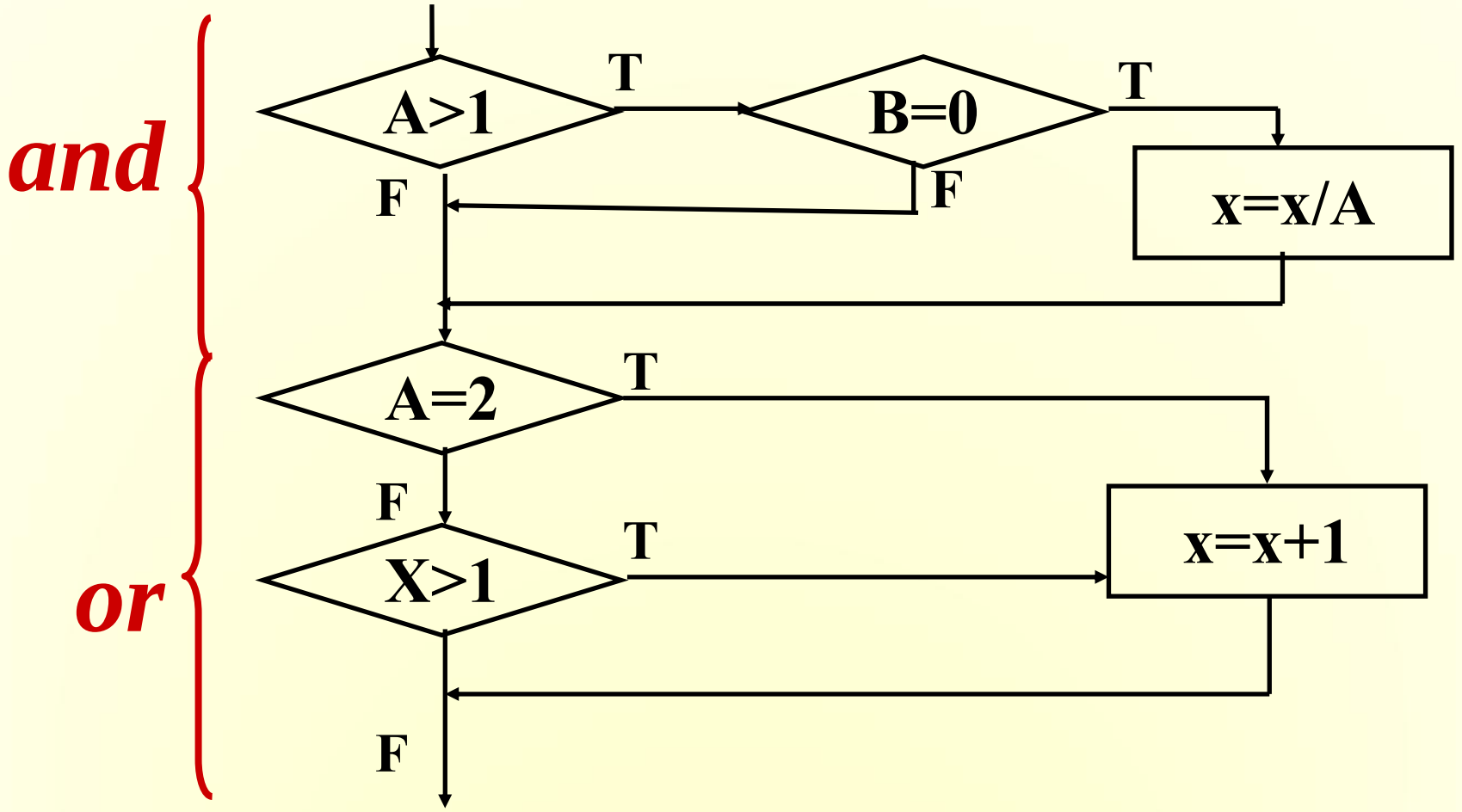
Test case
(2, 0, 4)
(3, 1, 1)

3.2 Logic Coverage—Condition / Decision Coverage

* Condition/decision coverage（*条件判断覆盖*） is to design sufficient test cases, make all possible conditions of each judgment implement at least once, and make all possible results of each judgment implement at least once.
* An example to meet this requirement.

Test case	Path	Condition value	Coverage branch
(2, 0, 4)	ace(L1)	T1 T2 T3 T4	c，e (T, T)
(1, 1, 1)	abd(L2)	!T1 !T2 !T3 !T4	b，d (F, F)

3.2 Logic Coverage—Decomposition



3.2 Logic Coverage—Condition Combination Coverage

- Condition combination coverage（*条件组合覆盖*） is to design sufficient test cases, make all possible condition combinations of each judgment implement as least once.
- If the test cases meet the condition combination coverage, then they certainly meet the decision coverage, condition coverage and condition/decision coverage.

3.2 Logic Coverage—Condition Combination Coverage

① A＞1, B=0 as T1T2

② A＞1, B≠0 as T1!T2

③ A≯1, B=0 as !T1T2

④ A≯1, B≠0 as !T1!T2

⑤ A＝2, X＞1 as T3T4

⑥ A＝2, X≯1 as T3!T4

⑦ A≠2, X＞1 as !T3T4

⑧ A≠2, X≯1 as !T3!T4

3.2 Logic Coverage—Condition Combination Coverage

Test case	Path	Coverage condition	Combination coverage No.
(2, 0, 4)	ace(L1)	T1 T2 T3 T4	① ⑤
(2, 1, 1)	abe(L3)	T1 !T2 T3 !T4	② ⑥
(1, 0, 3)	abe(L3)	!T1 T2 !T3 T4	③ ⑦
(1, 1, 1)	abd(L2)	!T1 !T2 !T3 !T4	④ ⑧

There are four paths altogether in the procedure. Although the four test cases above cover all condition combinations and 4 branches, only 3 paths are covered and the path "acd" is missed.

3.2 Logic Coverage—Path Coverage

* Path coverage（*路径覆盖*） is to design enough test case to cover all possible path in the procedure.

No.	Test case	path	Coverage condition
1	(2, 0, 4)	ace(L1)	T1T2T3T4
2	(1, 1, 1)	abd(L2)	!T1!T2!T3!T4
3	(2, 1, 1)	abe(L3)	T1 !T2 T3 !T4
4	(3, 0, 3)	acd(L4)	T1T2!T3!T4

3.2 Logic Coverage—Complete Coverage

- None of aforementioned coverage strategies can cover all test cases. We consider using the combination of them to achieve better coverage.
- Complete Coverage (*全覆盖*) = Condition Combination Coverage + Path Coverage

Test cases satisfy both condition combination coverage and path coverage

A B X	Path	Combination Covered	Condition Covered
2 0 3	a c e	① ⑤	T1 T2 T3 T4
2 1 1	a b e	② ⑥	T1 F2 T3 F4
1 0 3	a b e	③ ⑦	F1 T2 F3 T4
1 1 1	a b d	④ ⑧	F1 F2 F3 F4
3 0 3	a c d	① ⑧	T1 T2 F3 F4

* Exercise1

```
int Func_Check(bool a, bool b, bool c)
   {
          int x;
          x = 0;
          if  (a&&b&&c)
                x =1;
          return x;
}
```

which one can achieve statement coverage? （ ）

A. a = F, b = F, c = F　　B. a = T, b = T, c = F

C. a = T, b = T, c = T　　D. a = T, b = F, c = T

* Exercise2

```
int Fun_Check(bool a, bool b, bool c)
{
        int x;
        x = 0;
        if  (a||b||c)
                x =1;
        else
                x = 0;
        return  x;
}
```

which one can achieve decision coverage? （ ）

A. a = T, b = T, c = F ; a = T, b =F, c = F
B. a = T, b = F, c = F; a = F, b = T, c = F
C. a = F, b = T, c = T; a = F, b = F, c = T
D. a = F, b = F, c = T; a = F, b = F, c = F

* Exercise3

```
int Func_Check (int a, int b, int c)
{
        int x;
        x = 0;
        if  (((a==2)&&(b>2))||(c<0))
                x =1;
        else
                x = 0;
        return  x;
}
```

which one can achieve condition/decision coverage? （ ）

A. a =4， b = 7， c = 8； a = 7， b = 5， c = 4

B. a =2， b = 3， c = -2； a = 7， b = 5， c = 5

C. a =4， b = 3， c = 8； a = 7， b = 1， c = 4

D. a =2， b = 3， c = -2； a = 0， b = 1， c = 5

* Exercise4

```
int Score (int ChineseScore, int MathScore, int PhysicalScore)
{
    int x;
   x = 0;
   if  ((ChineseScore>80)&&( MathScore>=80)&&( PhysicalScore>=80))
            x =1;
   else
            x = 0;
   return  x;
}
```

which one can achieve condition/decision coverage? （ ）

A. ChineseScore = 70， MathScore = 90， PhysicalScore = 95

   ChineseScore = 70， MathScore = 70， PhysicalScore = 70

B. ChineseScore = 81， MathScore = 90， PhysicalScore = 82

   ChineseScore = 95， MathScore = 90， PhysicalScore = 93

C. ChineseScore =100， MathScore = 90， PhysicalScore = 82

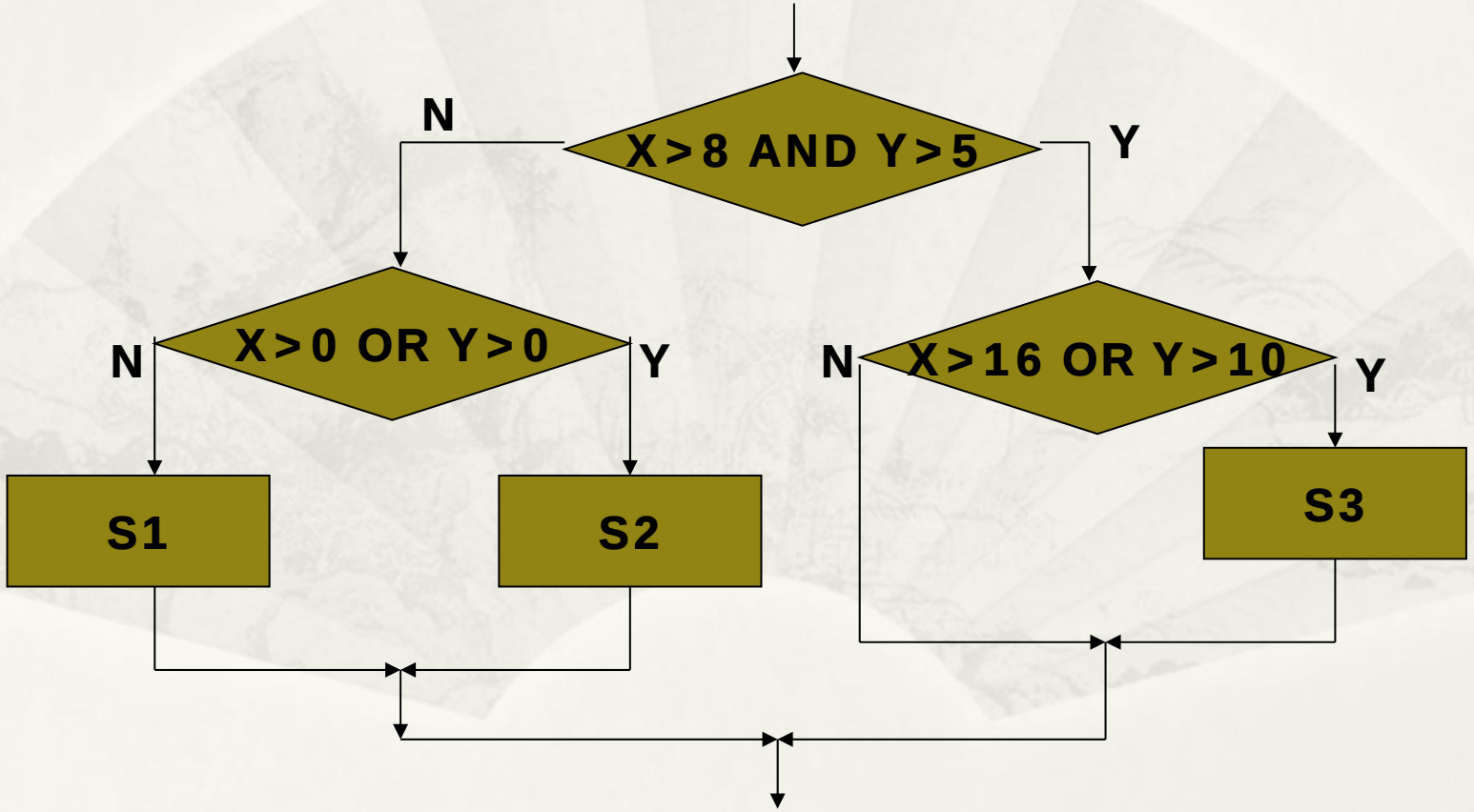
   ChineseScore =60， MathScore = 35， PhysicalScore = 44

D. ChineseScore =45， MathScore = 67， PhysicalScore =56

   ChineseScore =64， MathScore = 78， PhysicalScore = 77

Exercise 5

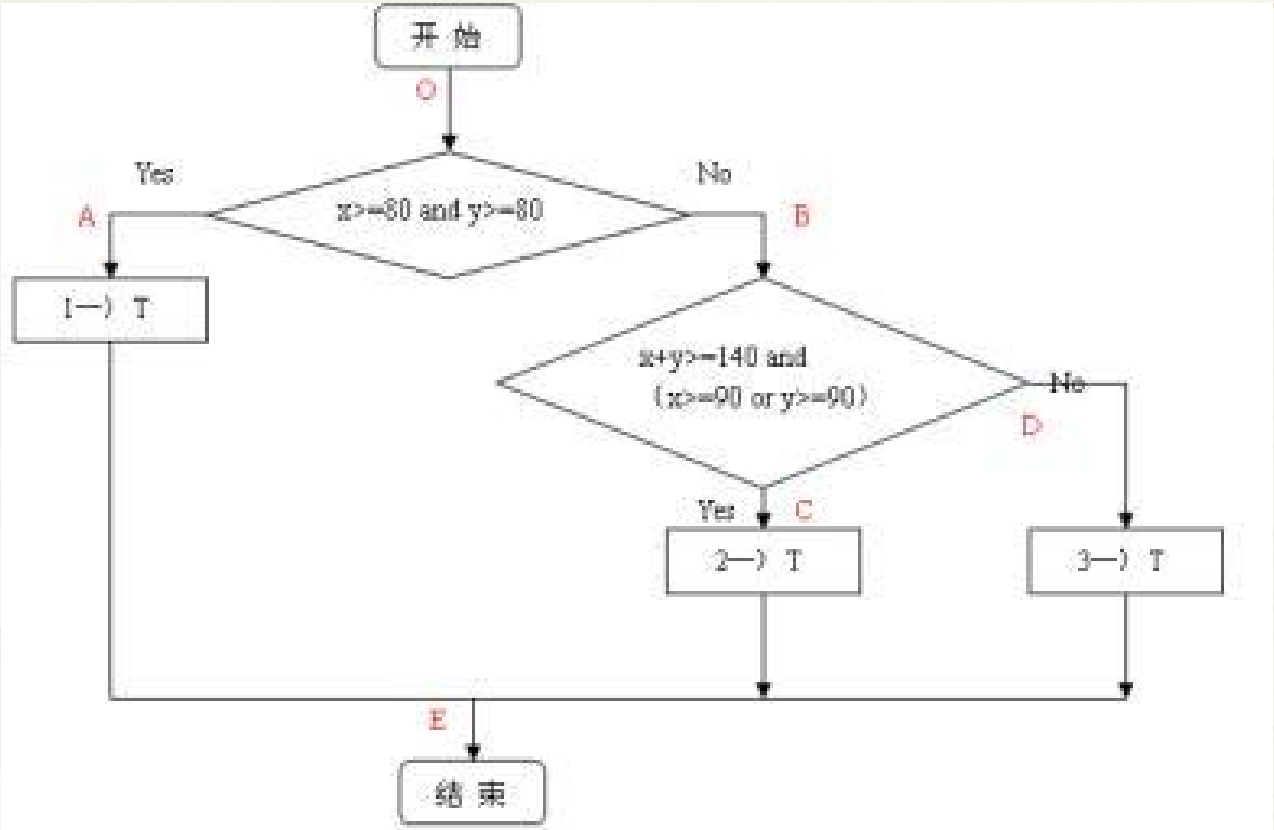
* Design test cases for the following flowchart to satisfy 7 types of coverage. (Note: X and Y are signed integers or 0)



Exercise 6

- Try to analyze the relationship among 7 different coverage strategies
  - Statement Coverage
  - Decision Coverage
  - Condition Coverage
  - Condition-Decision Coverage
  - Condition Combination Coverage
  - Path Coverage
  - Complete Coverage

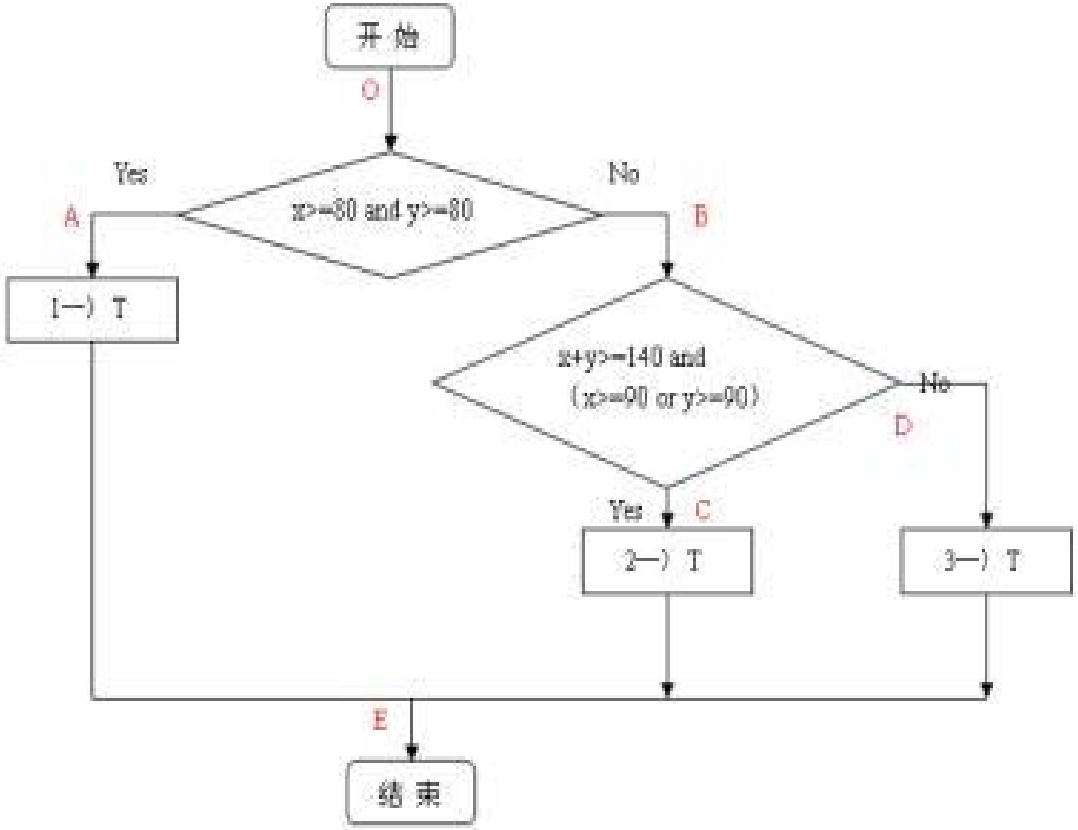
课堂练习2



语句覆盖测试用例
判定覆盖测试用例
条件覆盖测试用例
判定/条件覆盖测试用例
条件组合覆盖测试用例
路径覆盖测试用例

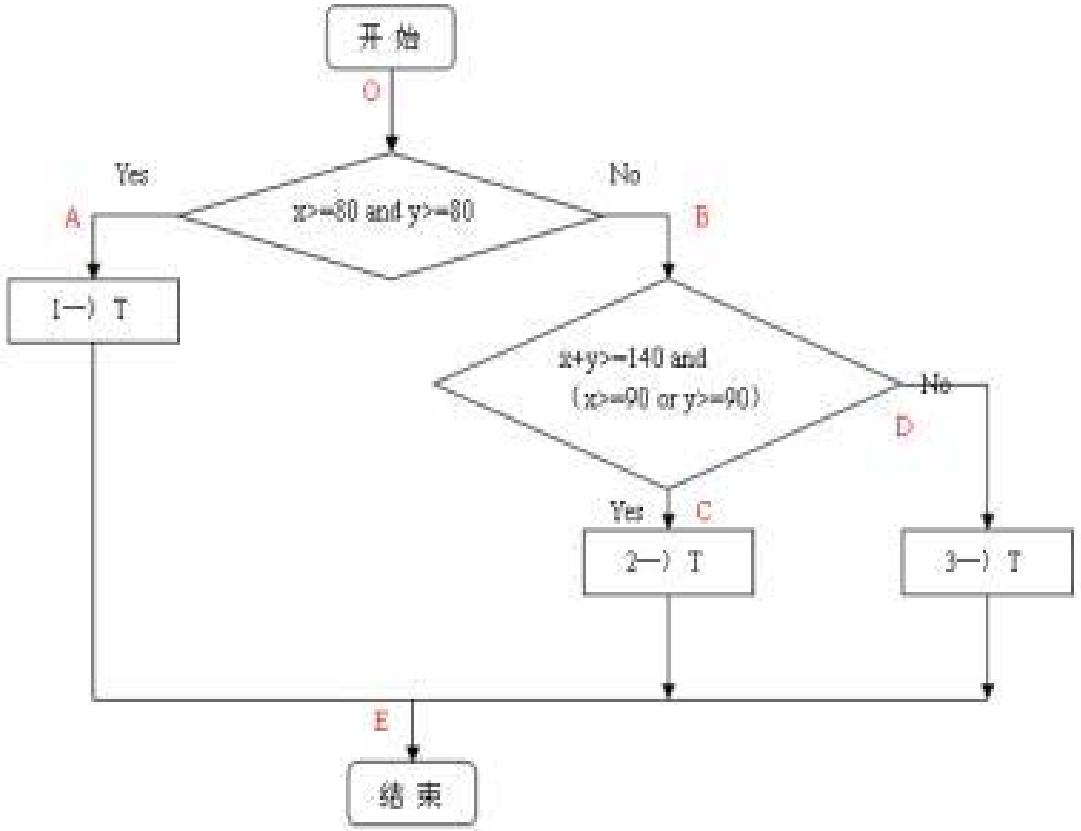
此题为1995年软件设计师考试的一道考试题目

1、语句覆盖测试用例



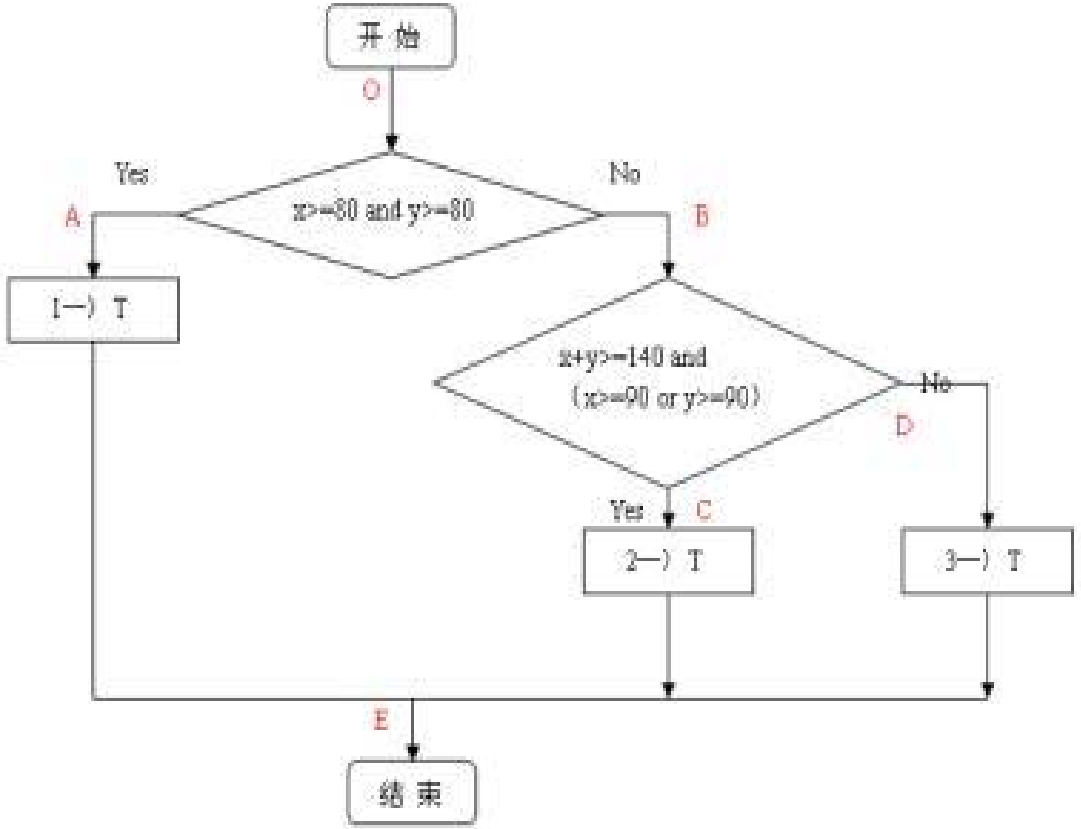
X	Y	路径
1	50	50	OBDE
2	90	90	OAE
3	90	70	OBCE

2、判定覆盖测试用例



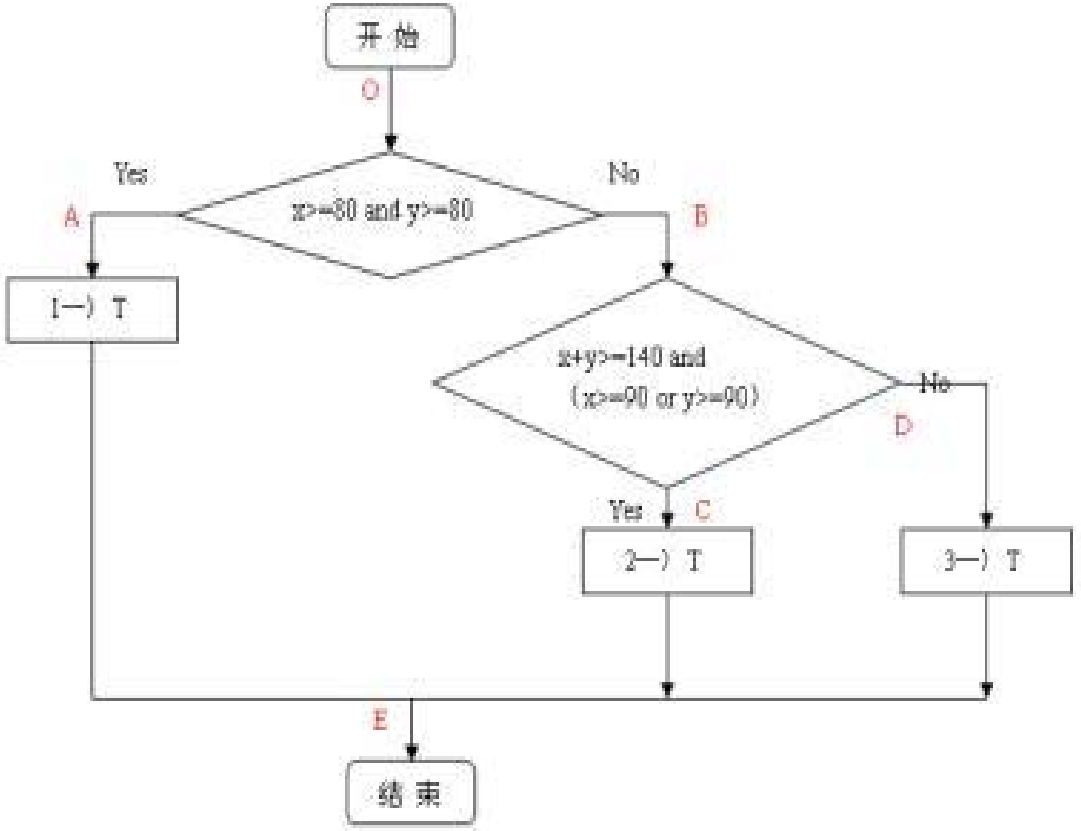
	X	Y	路径
1	90	90	OAE
2	50	50	OBDE
3	90	70	OBCE

3、条件覆盖测试用例



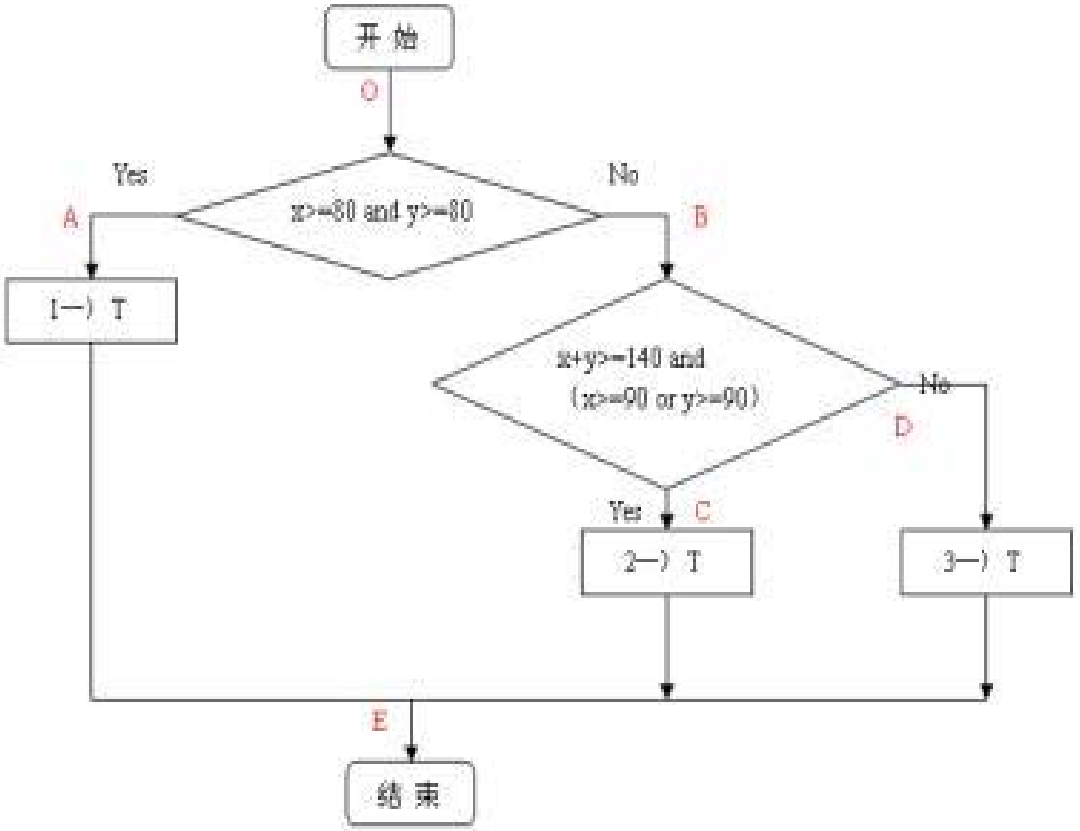
	X	Y	路径
1	90	70	OBC
2	40	90	OBD

4、判定/条件覆盖测试用例



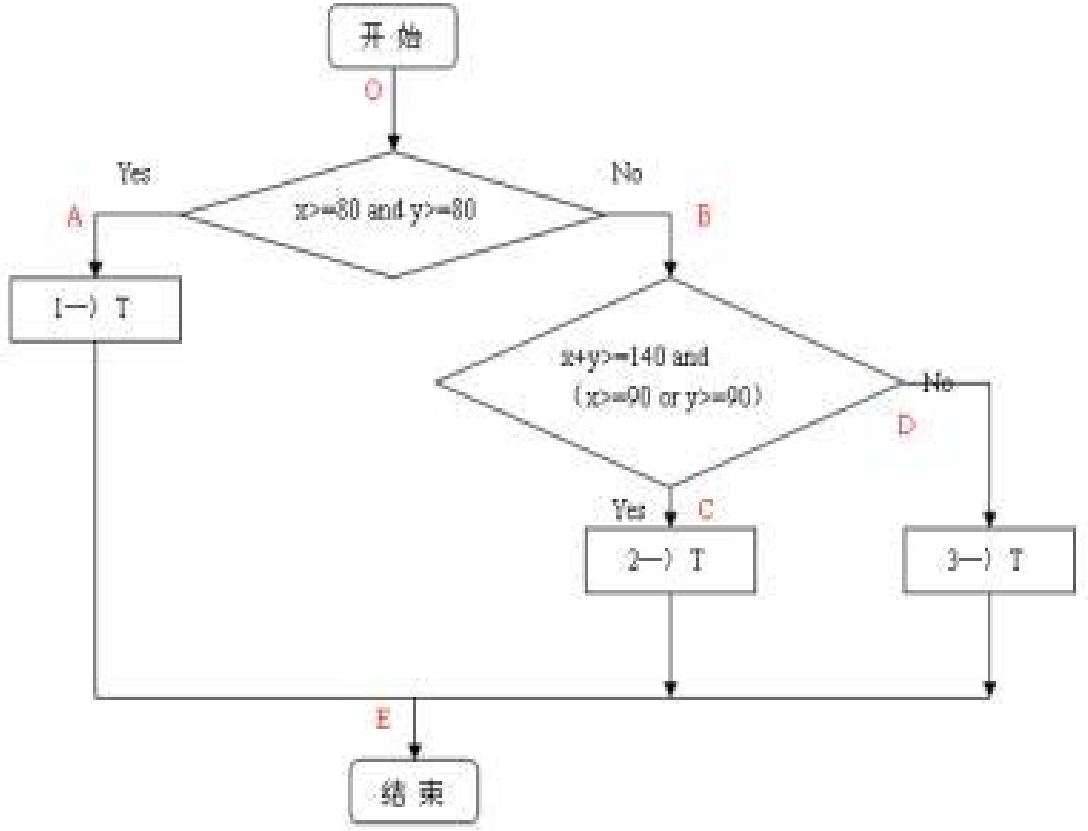
	X	Y	路径
1	90	90	OAE
2	50	50	OBDE
3	90	70	OBCE
4	70	90	OBCE

5、条件组合覆盖测试用例



	X	Y	路径
1	90	90	OAE
2	90	70	OBCE
3	90	30	OBDE
4	70	90	OBCE
5	30	90	OBDE
6	70	70	OBDE
7	50	50	OBDE

6、路径覆盖测试用例



	X	Y	路径
1	90	90	OAE
2	50	50	OBDE
3	90	70	OBCE

Modified Condition/Decision Coverage (MC/DC)

MC/DC

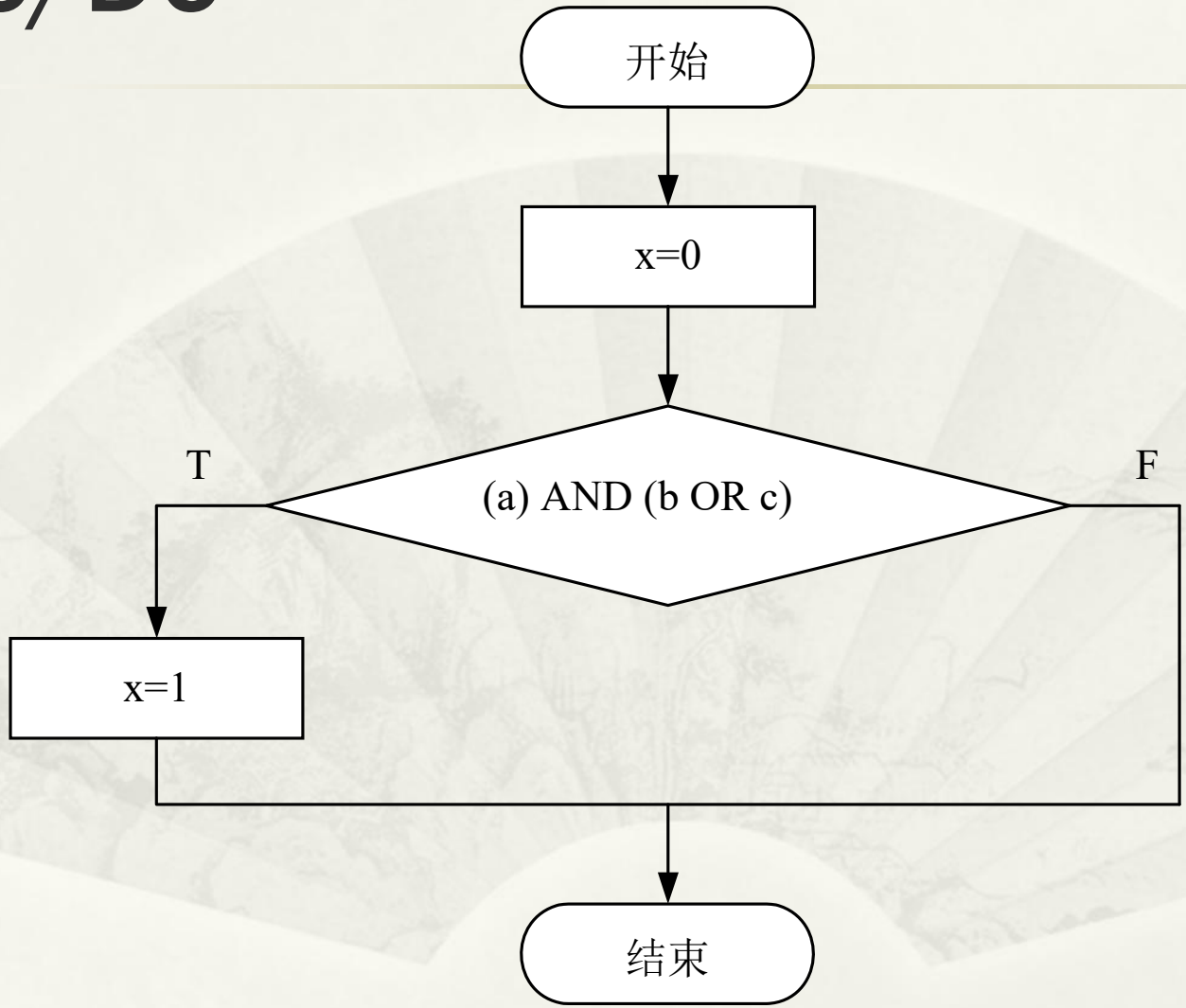
- A code coverage criterion that requires:
  - Each entry and exit point is invoked
  - Each decision takes every possible outcome
  - Each condition in a decision takes every possible outcome
  - Each condition in a decision is shown to independently affect the outcome of the decision.

MC/DC

* Independence of a condition is shown by proving that only one condition changes at a time.

* MC/DC is used in avionics software development guidance DO-178B and DO-178C to ensure adequate testing of the most critical (Level A) software.

MC/DC



```
int function1（bool a，bool b，bool c）
{
  int x=0;
  if(a&&(b||c))
     x=1;
  return x;
}
```

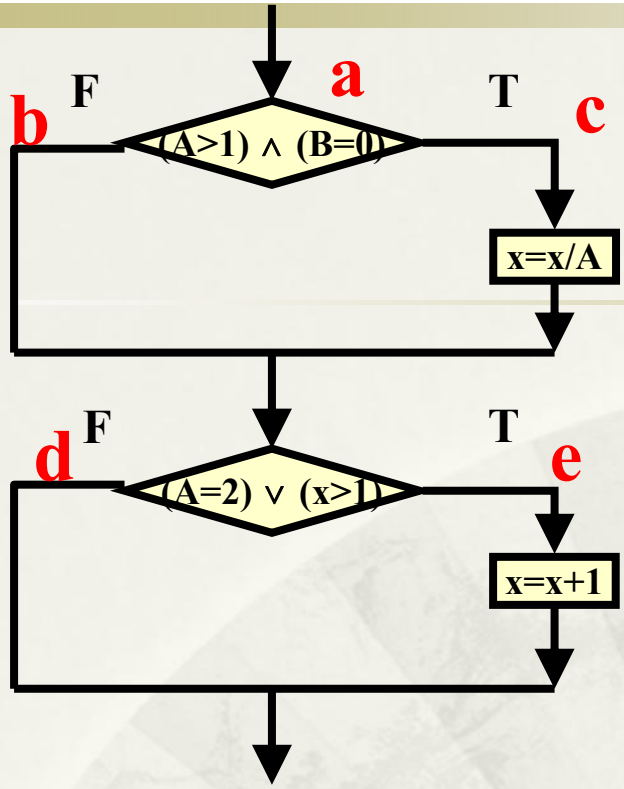
* Exercise
  * Decision coverage
  * Condition coverage
  * Condition combination coverage

MC/DC

序号	a	b	c	a&&(b||c)	a	b	c
1	T	T	T	T	5		
2	T	T	F	T	6	4	
3	T	F	T	T	7		4
4	T	F	F	F		2	3
5	F	T	T	F	1		
6	F	T	F	F	2		
7	F	F	T	F	3		
8	F	F	F	F			

$n+1 \sim 2^n$

{1, 2, 3, 4, 5} / {2, 3, 4, 6}



Path:

L1(a→c →e)

L2(a→b →d)

L3(a→b →e)

L4(a→c →d)

* Design test cases to satisfy MC/DC of this example.

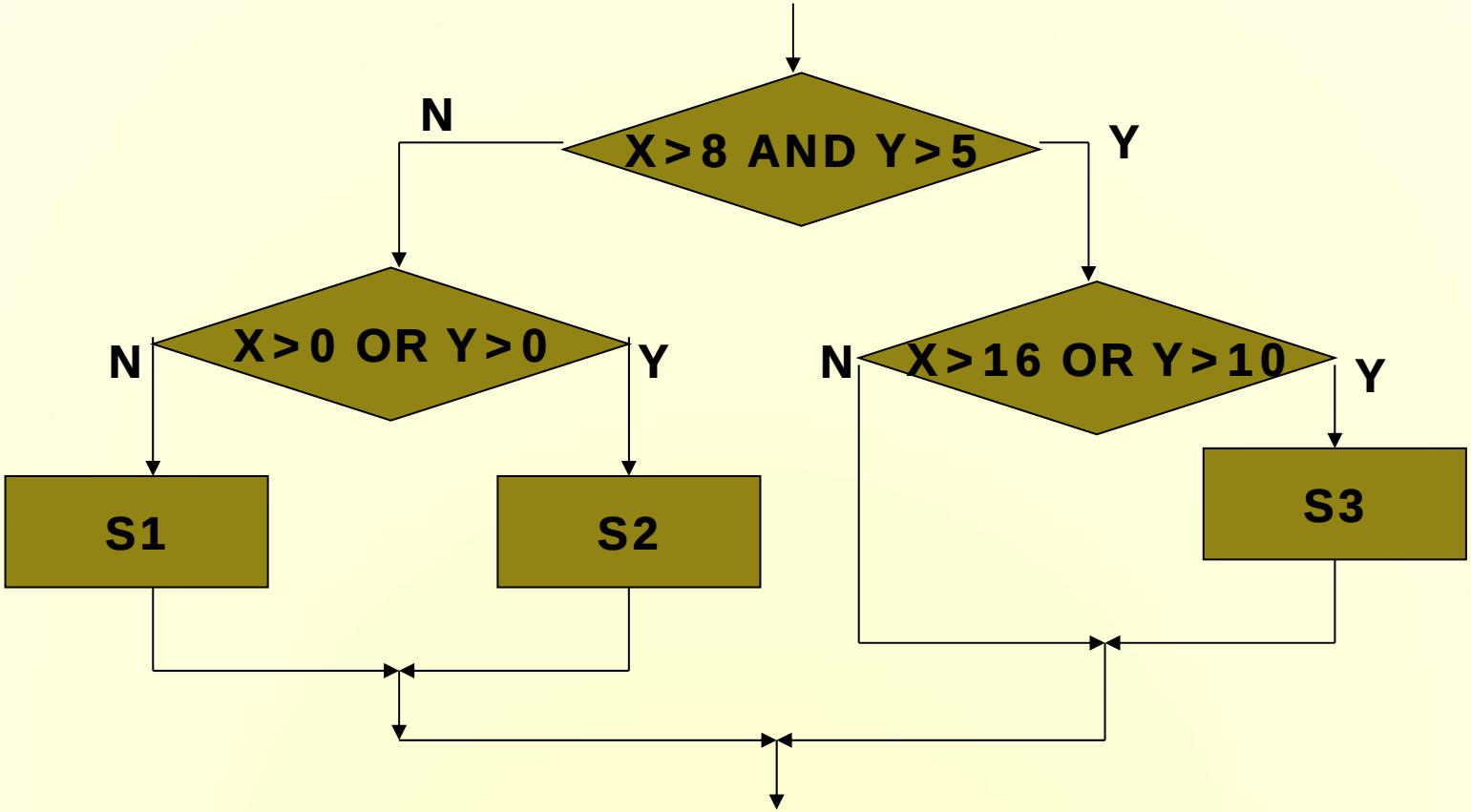
Test case	Path	Coverage condition	Combination coverage No.
(2, 0, 4)	ace(L1)	T1 T2 T3 T4	① ⑤
(2, 1, 1)	abe(L3)	T1 !T2 T3 !T4	② ⑥
(1, 0, 3)	abe(L3)	!T1 T2 !T3 T4	③ ⑦
(1, 1, 1)	abd(L2)	!T1 !T2 !T3 !T4	④ ⑧

MC/DC

- The MC/DC criterion is much stronger than the condition/decision coverage.
- The MC/DC criterion is NOT stronger than Condition Combination Coverage.
- Update Exercise 5/6

Exercise 5’

* Design test cases for the following flowchart to satisfy 8 types of coverage。(Note: X and Y are signed integers or 0)



Exercise 6'

* Try to analyze the relationship among 8 different coverage strategies
  * Statement Coverage
  * Decision Coverage
  * Condition Coverage
  * Condition-Decision Coverage
  * Condition Combination Coverage
  * Path Coverage
  * Complete Coverage
  * Modified Condition/Decision Coverage